MINISTRY AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH

LABORATORY LEAFLET
Number 71

Why fisheries need to be managed

Why technical conservation measures on their own are not enough

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LOWESTOFT
1993

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Lab. Leafl., MAFF Direct. Fish. Res., Lowestoft, (71): 15 pp.

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IMPORTANT NOTE:

The diagrams in the latter part of this leaflet involve major extrapolations from the current situation, and should only be regarded as illustrating the general effect of changing to much larger mesh sizes. They should not be taken as giving an accurate indication of management options in practice.

Why fisheries need to be managed

Summary

The classic argument for fisheries management and control is based on the fact that, in the absence of regulation, natural economic forces lead to a state of over-exploitation by any rational criteria. This involves unnecessarily high fishing effort to take yields which are less than the maximum possible, coupled with severe reductions of spawning stock size leading to increased risk of stock collapse. Catch-per-unit of effort is reduced to the point where the fishery becomes chronically unprofitable on average.

According to strict *laissez-faire* economics even these reasons may not be regarded as sufficient to justify intervention, unless imminent stock collapse can be demonstrated. More detailed analysis however shows that:

(a) the *laissez-faire* bio-economic ‘equilibrium’ is probably not stable, so that the industry is likely to over-react to fluctuations of recruitment or prices in a violent boom and bust manner, greatly increasing the risk of stock collapse;

(b) continuing investment for improved efficiency can lead to short-term increases of profitability which are temporary, and can only be maintained by further investment. This leads to a vicious circle as a result of which the stock is likely to be systematically reduced to the point of collapse.

Both of these dynamic considerations considerably reinforce the already powerful classical argument that management of fisheries is needed for effective conservation in support of management for conservation.

INTRODUCTION

The classic argument for the need to manage fisheries is based on a simple analysis. This shows that, if unregulated, natural economic forces will cause fishing effort to expand to a point where the average fisherman can only just break even on his operating costs. This means that he generates no operating surplus with which to pay off his loans, or put towards improving or replacing his boat. The fishing industry becomes chronically marginally unprofitable, leading to continual demands for aids and subsidies. At the same time, the total effort directed at the fish stocks on which the fishery depends grows well beyond the level needed to take the maximum possible yield of fish, and the stock size is reduced well below the level that would enable that maximum yield to be taken. The small stock size means that there is no buffer to cushion the stock and the fishermen against the effects of varying recruitment of young fish — especially the effects of one or two years of poor recruitment. It may also lead to reduced recruitment, even possibly to the point of complete collapse of the stock.

THE CLASSICAL BIO-ECONOMIC EQUILIBRIUM

The reasoning behind these statements can be followed by reference to Figure 1. This shows the classic dome-shaped long-term production curve of a fish stock expressed in terms of the value of the landings (see Laboratory Leaflet No 70 for an explanation of this curve, and the details of the response of fish stocks to exploitation in what follows). Also shown are the costs of fishing, taking into account only the short-term variable costs of fishing more or less hard, and leaving aside for the moment the fixed costs of servicing debts and replacing boats. The costs are assumed for simplicity to be directly proportional to the amount of fishing effort. This is not a bad approximation, and the details do not affect the argument. It is easily seen that, if the total fishing effort is fairly low, for example at the level marked 'A', then earnings exceed costs, so that, on average, fishing is profitable, and there will be natural tendency for total fishing effort to increase, as individual fishermen respond by increasing their effort, and new entrants are attracted to the fishery.

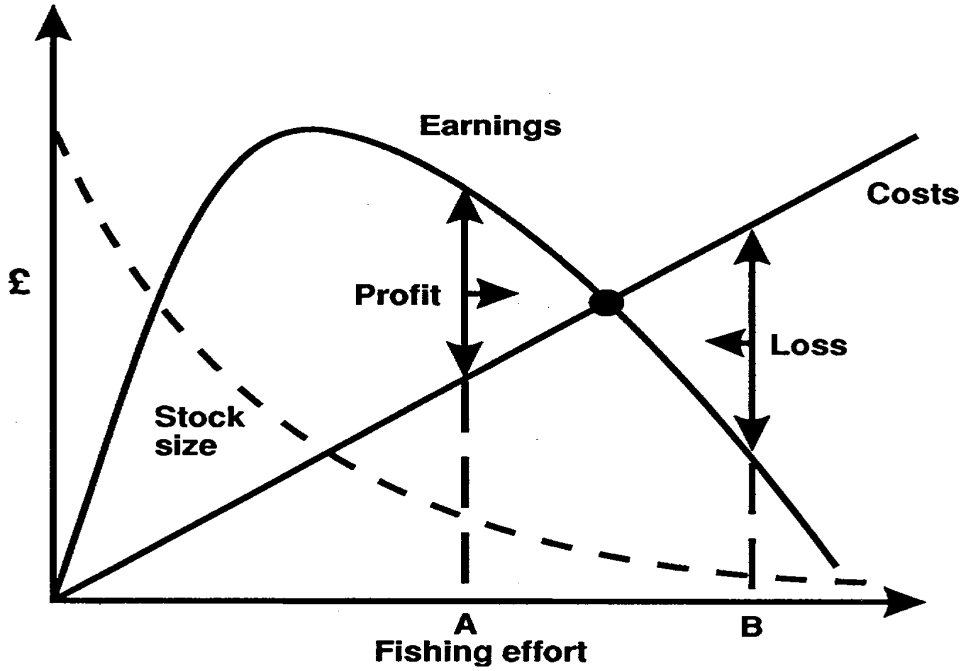

Figure 1. The balance of cost and earnings and the 'bio-economic equilibrium'

Conversely, if fishing effort is relatively high, for example at the level marked 'B', then costs exceed earnings, fishing is unprofitable, and there will be a tendency for fishing effort to decrease. Fishing effort should therefore stabilise at the intersection of the costs line and earnings curve. This point is known as the 'bio-economic equilibrium'. Here there is on average no operating surplus. The potential surplus available at lower effort (eg, level 'A') has been reduced to zero. An economist would say that the 'rent' had been dissipated. Figure 1 also illustrates the typical effect of fishing on stock size. At this position of unregulated equilibrium it is common to find that the spawning stock has been reduced to less than 10% of its unfished level. In some cases (including North Sea cod) the spawning stock has been depleted to just 1% or 2% of the estimated unfished level. It is little short of miraculous that such stocks are able to maintain a level of reproduction which is sufficient for them to survive.

WHY THE 'EQUILIBRIUM' MAY NOT BE STABLE

There is no guarantee that the so-called 'equilibrium' discussed above is in fact stable. The reason for this is that fish stocks do not react instantaneously to changes of fishing effort. It takes a little time — typically a few years — for the full effects of any change to work through the stock. This means that any increase of effort leads to a short-term increase of landings (and earnings) and a period of grace before the eventual long-term loss indicated in Figure 1 becomes apparent. At the same time, the industry does not react immediately to any perceived change in profitability. Some fishermen will react very rapidly. Others may need to change their gear, modify their boats, or even buy a new one in order to increase their effort, or they may simply be more conservative in their behaviour. Similarly it takes time for a reduction in effort to occur when the fishery becomes unprofitable.

These two finite rates of change—of the fish stock in response to a change in fishing effort, and of fishing effort in response to a change in the stock abundance—may combine in an unfortunate way. By the time the industry has reacted to a temporary increase of the stock, caused for example by good recruitment of young fish for a year or two, and increased its effort because of the improved profitability, the stock will most probably have returned to a more normal state. Now, however, the increased effort drives the stock size further down. This of course reduces profitability, and the industry should react by reducing effort again. By the time this happens, and the effects become apparent, it may however be too late. The stock may have been driven below a biologically sustainable level, and collapse.

The process is illustrated in Figure 2. The bold arrows indicate the direction of change of effort and catches once the stock has been perturbed and moved away from the bio-economic equilibrium point. The potential for a vicious circle of events to build up is clear. Whether or not the system settles down, spiralling back in towards the 'equilibrium' or becomes genuinely unstable, spiralling out until the stock collapses, depends on the rates at which the stock and the industry react, and the time lags involved. This process can be analysed mathematically, but the moral is clear: it would be unwise to assume that the natural bio-economic forces are benign. They may just as easily lead to collapse as to a stable equilibrium, and experience with unregulated fisheries suggests that they do.

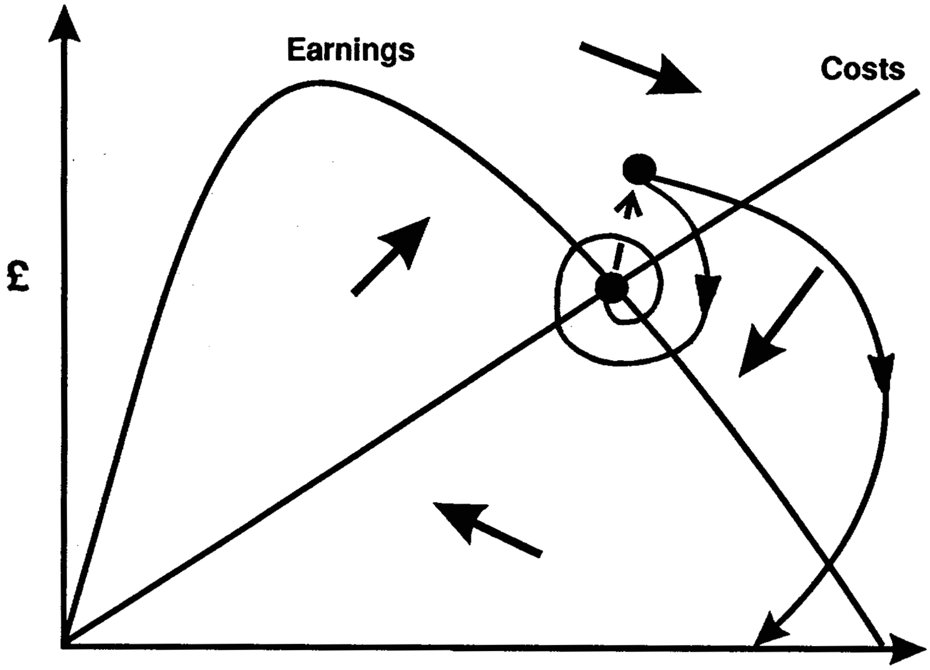

Figure 2. Dynamic response of catches and fishing effort (broken arrow indicates a perturbation due to good recruitment)

WHY THERE MAY BE NO EQUILIBRIUM

A further problem may arise because of the finite speed at which the stocks react to changes of fishing effort. Consider the effect of an improvement in efficiency which increases the effective fishing effort at little extra cost (or maintains the existing effort at a lower cost), as shown in Figure 3. If this occurs, there will be a short-term increase in catches and earnings, and therefore of profitability. If no further increase in efficiency occurred, the system would (eventually) settle at a new equilibrium, with, in the long run, higher effective effort, and lower costs and earnings, at a reduced stock size. However, it is likely that some of the temporary increase in profits would be re-invested in further improvements in efficiency, leading to a repeat of the same processes. This can be repeated over and over again, and in practice the stock may never reach a new bio-economic equilibrium, but may be driven down to progressively lower and lower stock sizes, until finally it collapses, as illustrated in Figure 3.

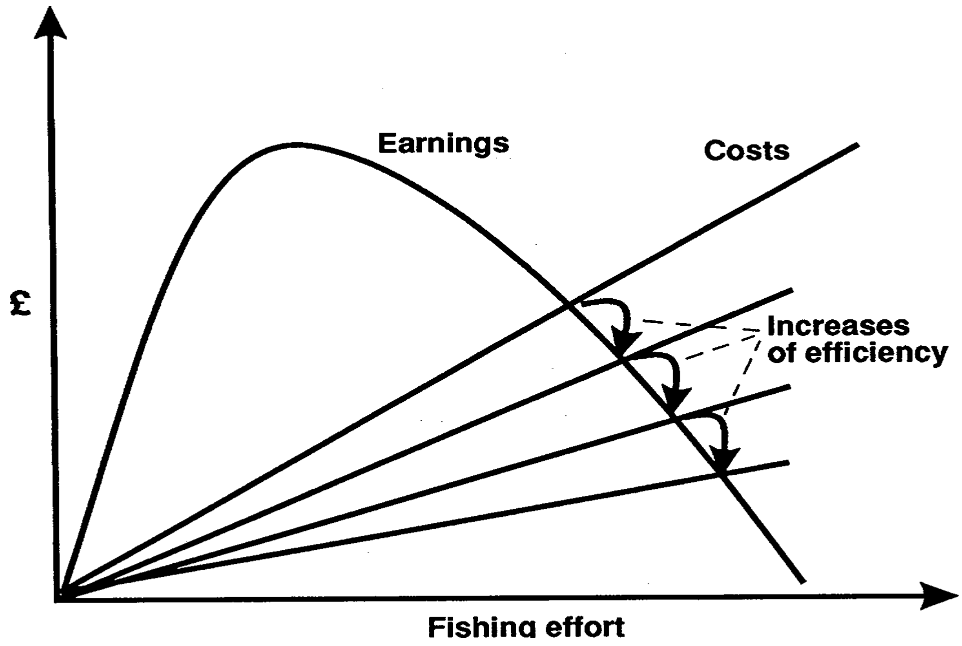

Figure 3. Dynamic response to increasing efficiency

CONCLUSIONS

Fisheries usually need to be managed because:

(a) they are common property resources, and the actions of individual fishermen acting in their own interests have adverse effects on the others;

(b) normal market mechanisms tend to bring the fishery to a state where, on average, fishermen only earn enough to cover their short-run operating costs, leaving no surplus for the servicing or replacement of capital invested;

(c) the unregulated bio-economic equilibrium point for the fishery may be unstable because of the dynamics of the responses of the fish stock to exploitation, and of the fishermen to the profitability of the fishery. Both simple time lags in the responses, and the effects of improvements in efficiency, may easily lead to increasing levels of exploitation which eventually drive the stocks down to the point of collapse.

It is therefore not possible to rely on simple market forces to bring fisheries into a satisfactory equilibrium state, and co-operative action or government intervention are usually required. Technical conservation measures are not usually sufficient to correct the problem, since they only alter the efficiency of the fishing operation, and bring the fishery to a different but also potentially unsatisfactory state. Direct conservation measures, such as limitation of catches and/or fishing effort, are usually required to address the biological and economic problems created by the failure of the market mechanism.

Why technical conservation measures on their own are not enough

Summary

Technical conservation measures such as minimum mesh sizes affect the composition of catches of fish, and usually aim to prevent the capture of too many small and immature fish. They do not however directly restrict the total quantity of fish caught. Unless the minimum mesh size is large enough that at least one mature age group escapes capture entirely, an increase of fishing effort, and the associated deaths of immature fish, will cause a decrease in the spawning stock size. With practicable restrictions on mesh sizes, etc, it is therefore usually still possible to deplete the size of the spawning stock to a very low level by excessive fishing effort, and the associated excessive catches.

To prevent this, without restrictions of fishing effort, it would be necessary to introduce technical measures which, roughly speaking, ensured that a high proportion of fish had the opportunity to spawn at least once. For large fish, such as cod, this would mean minimum landing sizes (about 60 cm) and mesh sizes (approaching 200 mm) which are much larger than those presently in use. This would of course prevent the capture of smaller fish such as haddock and whiting, and is hardly practicable in a mixed fishery.

Furthermore, unless the technical measures were so restrictive that they made the fishery completely uneconomic, they would not prevent any increases of effort if, for example, fish prices increased, with adverse effects on the stock in consequence.

Realistic technical conservation measures — including spawning season closures — on their own are therefore generally not sufficient to ensure effective conservation, at least for large fish, and they usually need to be supported by direct conservation measures such as limits on catches and/or on fishing effort. These limits can however be made progressively less restrictive as the technical measures employed are made more effective.

Exclusive reliance on technical measures has in fact been tried in several parts of the world — with the expected consequences that fishing effort continues to increase until the stocks are severely reduced and the fisheries become uneconomic.

INTRODUCTION

Catching fish increases their death rate, and so reduces the proportion of older fish in the population. However, fish grow as they get older, and they tend not to reach sexual maturity until they reach a certain size. It is therefore important that sufficient fish survive and grow enough to reach maturity, and are therefore able to spawn and contribute to the next generation.

This can be achieved in two ways. First, by ensuring that few young fish are caught before they mature, by technical conservation measures such as minimum landing sizes, minimum mesh sizes, and closed areas (especially nursery areas, often in shallow water, where young fish congregate). Second, much the same effect can be achieved even if young fish are caught, by ensuring that the total death rate is kept sufficiently low. This is done by direct conservation measures, such as limits on catches or on fishing effort. These aim to limit the quantity of the catch (and therefore the death rate) and not just the size and age composition of the catch, as technical conservation measures do.

Generally, both types of conservation measures are used together. However, in some cases, for example midwater trawling and purse seining for shoaling pelagic fish such as herring and mackerel, mesh selection is much less effective because the catch itself blocks and blinds the meshes of the nets. In such cases the death rate must be limited mainly by controls on catches or fishing effort, or by closed areas and seasons.

Direct controls on catch and effort of course limit fishermen's incomes, and are therefore unpopular. For dispersed bottom-living demersal fish such as cod, haddock, plaice and so on, for which mesh selection is effective, it is sometimes questioned whether technical measures on their own would be enough. These are of course also unpopular (as quickly becomes apparent when there is any suggestion that the minimum mesh size might be increased), but perhaps a little less so. They also tend to reduce incomes because they prevent the capture, landing and sale of smaller fish. They do however only limit the rate of earnings per unit time, and leave individual fishermen the option of maintaining or increasing their total earnings by working harder, unlike catch quotas which ultimately set an upper limit on total earnings.

The answer to the question, whether technical measures on their own would be enough to ensure effective conservation, is quite simple. It is an unfortunate fact of life that for many species of fish, especially larger ones such as cod and plaice, the minimum size of fish caught is smaller than the mean size at which the fish first became mature, and the answer is no. The reasons for this are explained below. To increase the minimum landing and mesh sizes sufficiently to protect these species would prevent other smaller species such as haddock, whiting and soles being caught at all, and is regrettably not usually a practical proposition.

AGE, SIZE, MATURITY AND STOCK SIZE

Figure 1 illustrates the growth and maturation of North Sea cod. This shows that most of the fish do not mature until they are about four years old, at a mean length of more than 60 cm. The present minimum landing size is 35 cm, and the current mesh size permits some even smaller fish to be caught, so lots of young fish are caught before they have a chance to spawn at all.

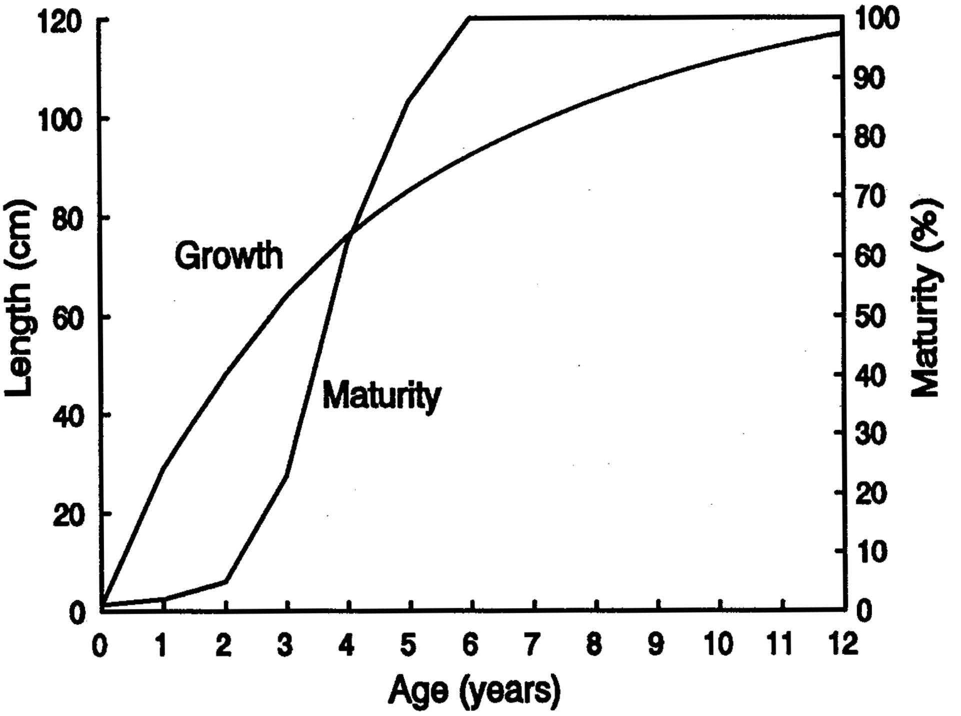

Figure 1. Growth and maturation of North Sea Cod

Figure 2 shows estimates of the average age composition of the stock, with those which are mature emphasised, for an unfished population of this stock. There are, for all practical purposes, no mature fish of less than three years of age, and the bulk of the spawning stock is made up of fish which are five or more years old. These estimates are of course rather uncertain, because the maturation and mortality rates for an unfished stock would probably be different from those we see now. Nevertheless, the general picture would remain as shown.

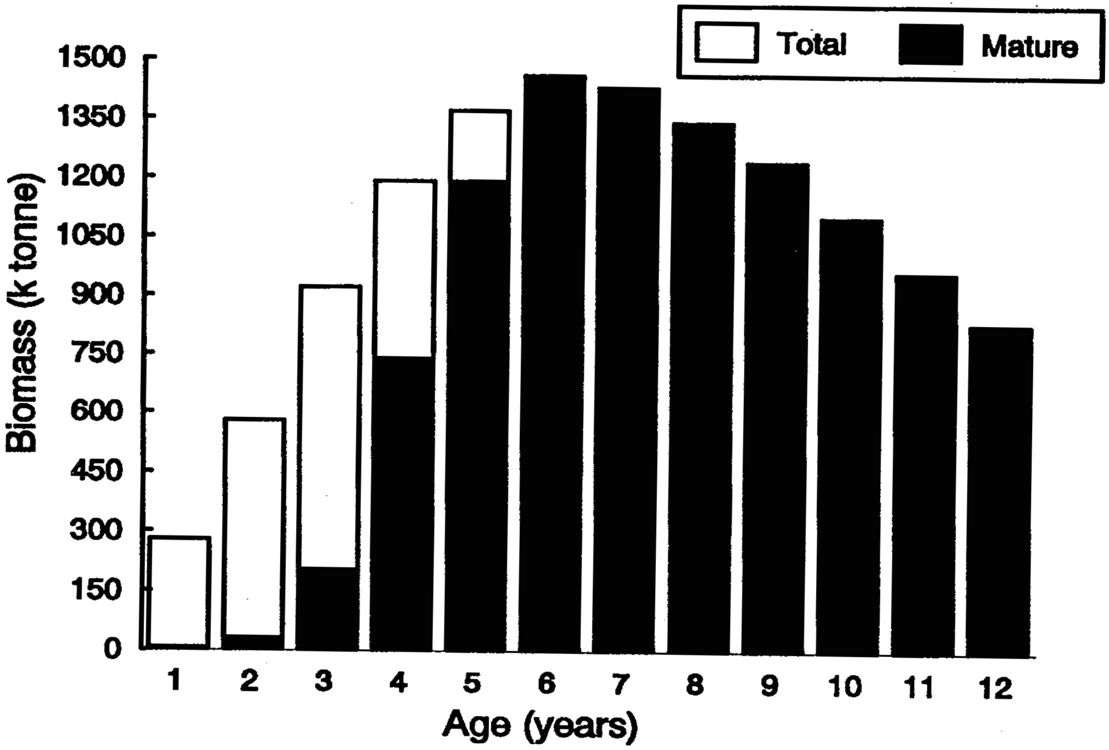

Figure 2. Age composition of the biomass of an unfished stock of North Sea Cod

Contrast this with the composition of the stock at the current level of fishing, shown in Figure 3. The present exploitation pattern on North Sea cod (created by a minimum mesh size of about 100 mm) is such that virtually all fish of two or more years old are subject to about the same level of fishing mortality (the death rate due to fishing) and some one year old fish are caught too. Clearly the numbers of older fish have been dramatically reduced (note the change of scale) and there are very few fishes aged four or more to contribute to the spawning stock. It is really little short of miraculous that the stock continues to produce sufficient young recruits to replenish itself from such a reduced spawning population.

Figure 4 shows what the average composition of the stock would eventually become, for the current level of fishing effort, if the mesh size used were 200 mm. Clearly the size of the spawning stock is much increased compared with the present level, because the numbers of fish at age are similar to those of the unfished stock up to about age four. The high death rate only applies to the older fish, and there are always a reasonable number of mature fish of age four or five, and quite a few older ones. This would still be so even if the fishing effort were to become much higher, because the higher death rate would still apply mainly only to fish aged five or more.

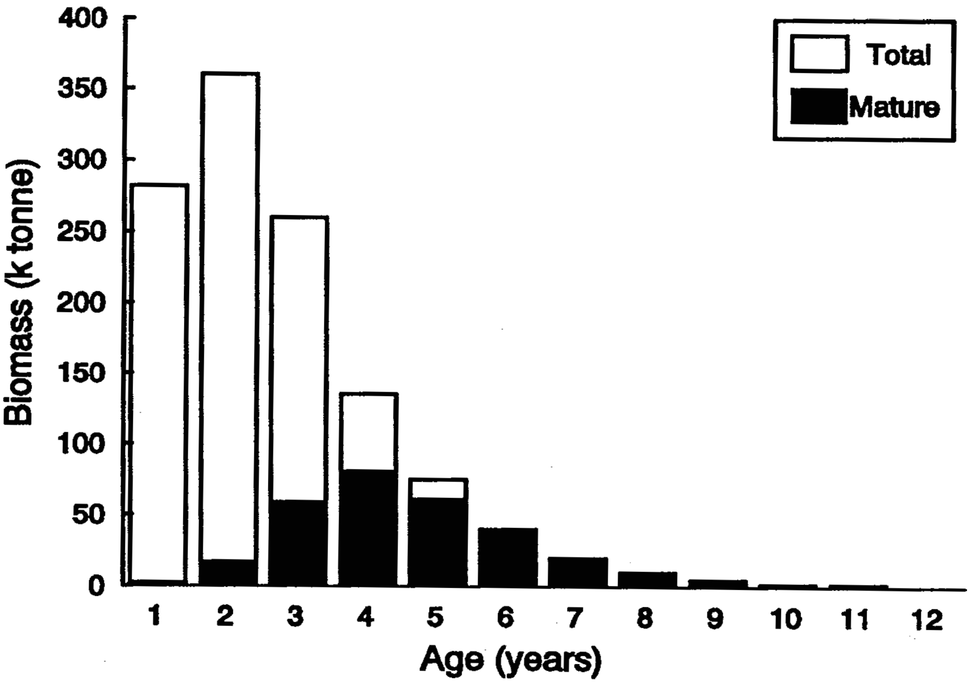

Figure 3.Age composition of North Sea Cod biomass at current rate of fishing and mesh size (100mm)

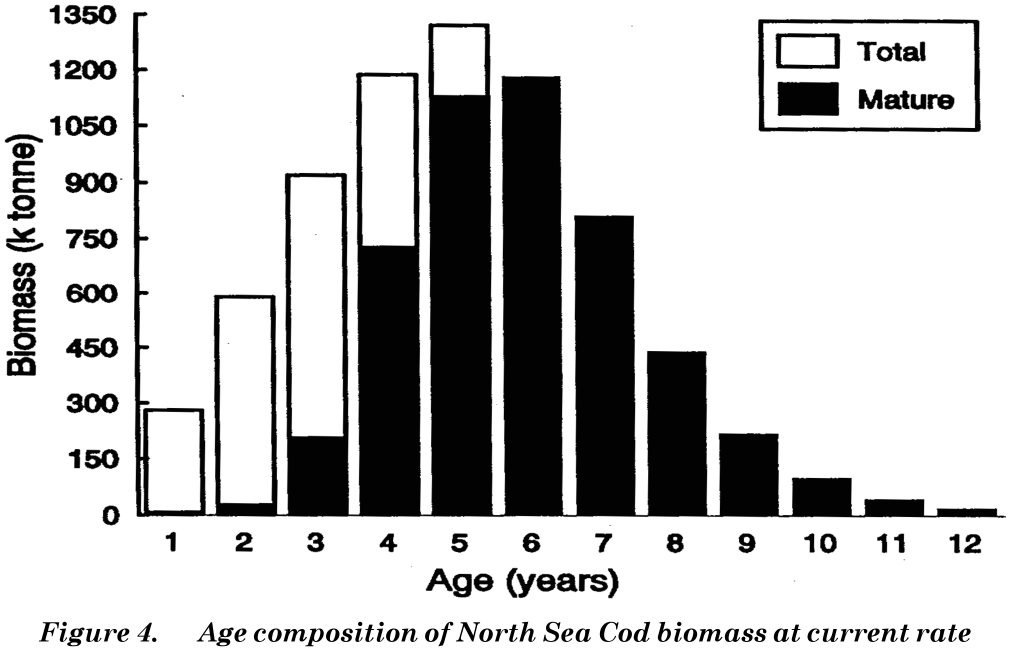

Figure 4. Age composition of North Sea Cod biomass at current rate of fishing with 200 mm mesh

The overall effect on spawning stock biomass is summarised in Figure 5, for fishing effort up to twice the current level, and for a range of mesh sizes between the current size and double that size. It is easily seen that with the current mesh size the spawning stock size falls rapidly as fishing pressure increases, and continues to decline to very low levels up to and beyond the highest levels of exploitation considered here. Conversely, with the largest mesh sizes, the curves tend to flatten out so that further increases of fishing effort have relatively little effect. This is because, as explained above, once the older age groups have been fished out, the spawning stock is sustained by those newly matured smaller fish not subject to significant fishing pressure

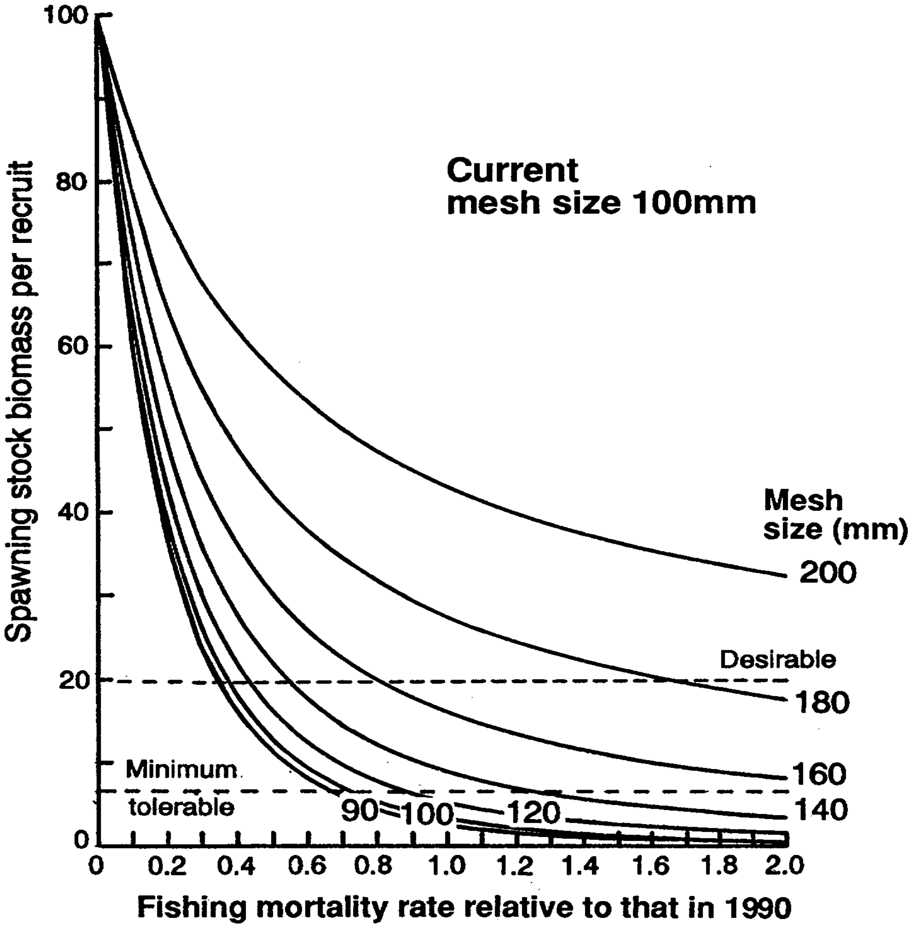

Figure 5. Effect on spawning stock biomass of fishing, for various mesh sizes

.SPAWNING STOCK SIZE - HOW LOW IS TOO LOW?

Also shown on Figure 5 are two reference levels of spawning stock size (assuming average recruitment of young fish). These are:

(a) twenty per cent of the unfished level, widely considered to be a minimum desirable level;

(b) the level corresponding to the biological reference point called F_{med}. This is regarded as a minimum tolerable level because only above it does the stock have a better than even chance of producing enough recruits to maintain its size. It corresponds to the current scientific recommendation for the North Sea roundfish stocks.

Even with a 120 mm mesh size, modest increases of fishing effort above the current (1990) level could push the stock below the minimum tolerable level. To be reasonably sure of staying at a sustainable (although small) level of stock size, even if effort were to increase substantially, would require a mesh size of at least 140 mm. To reach the desirable level of stock size at current levels of fishing would require a mesh size of at least 160 mm, and to be confident of reaching the desirable level even if fishing effort were to increase substantially, would require a mesh size of 180 mm or more.

Thus, for North Sea cod, the increases in mesh size required to enable restrictions on catch and effort to be lifted are such that this is hardly a practical proposition. Similar results would be obtained for any large species of fish, such as plaice, turbot or monkfish. One is forced to the conclusion that, in a mixed fishery, management using technical measures alone would not be effective, unless one were prepared to accept that all the large (and often most valuable) species would be fished out completely. This has been demonstrated in practice by American experience on Georges Bank, where management has relied mainly on a minimum mesh size of 5½"(140 mm) for the last ten years or so, and levels of cod, haddock and yellowtail flounder have declined to extremely low levels. Similarly, in the North Sea, very large species which were abundant prior to the twentieth century, such as halibut, ling and even turbot, are now relatively rare.

IMPLICATIONS FOR MANAGEMENT

Since most UK demersal fisheries are aimed at a mixture of species, and since 'large' species such as cod and plaice are caught in almost all of them, one must conclude that technical measures alone are not enough for effective conservation. A balanced combination of direct and technical conservation measures is required. For each species one can produce results such as those illustrated in Figure 5, and read off combinations of mesh sizes and effort levels which would lead to the same level of spawning stock size in the long run, and may therefore be regarded as equivalent. For a single species this is fine, but for mixed fisheries some compromise has to be found between the desirable (or tolerable) combinations for the various species concerned, which will of course be different. For this reason, direct conservation measures often emerge as the most effective tool, because effort reductions broadly conserve all species in more or less the same way. Technical measures, on the other hand, tend to be much more species-selective, because minimum mesh sizes in particular are effective for conserving small species, but not for large ones. Since it is often the large (and generally valuable) species which are most at risk, the effectiveness of practicable mesh increases is often quite limited.

CONCLUSIONS

Technical measures are not an easy solution to the problem of fisheries management. To be effective they usually need to be complemented by limitation of catch and effort. Ultimately, the only way to conserve fish is to kill fewer of them, and whether this is done by direct conservation measures or by technical measures is of less importance. This means catching fewer fish, and thus, at least in the short term, probably a reduction in fishermen's earnings. The uncomfortable fact is that a conservation measure which avoids any short-term loss is most unlikely to be effective. If it doesn't hurt, it won't work.

APPENDIX. CLOSURES OF SPAWNING FISHERIES

Another technical measure which is often proposed, especially by fishermen, is closure of fisheries on spawning grounds during the spawning season. At first sight it seems that this should be a very effective conservation measure. Indeed, if the spawning fisheries were closed and the fishing effort and catches which would have been taken were not simply displaced elsewhere, or to later in the year, it could well be helpful. Unfortunately, however, such a permanent reduction of fishing effort and catches is rarely what is proposed. The question of what should happen to the effort displaced and the catches foregone is rarely considered explicitly. It is usually assumed, however, that it would be possible for the fishermen to catch the same quantity of fish elsewhere, or later in the year. If this is the case, a spawning season closure could actually make matters worse, because it could shift effort off spawning fish (which are by definition mature and getting the opportunity to spawn at least once) and on to juvenile fish: this is of course the opposite of what is required. Even if this does not happen, and the effort merely shifts to the same fish later on, the effect is only a one-off boost to the spawning stock. In the first year of implementation, more fish get a chance to spawn than did previously. After that, however, the numbers being caught between one spawning season and the next would be just the same, and the effect is at best just the same as delaying the age of capture by a few months. If — as is quite likely — the effect is in fact to move the fishery on to pre-spawning rather than spent fish, then the effect would be equivalent to decreasing the age of first capture, which would be bad for the stock.

Closures of spawning fisheries are therefore not as effective as conservation measures as they may seem at first, although where spawning fish are highly concentrated in small areas, or especially easy to catch, a spawning season closure may help simply by making fishing less efficient. Even this would however still only be effective if the total catch or effort were controlled.

FURTHER READING

Laboratory Leaflet No 54:	Background to scientific advice on fisheries management J G Pope (1982)
Laboratory Leaflet No 58:	Why increase mesh sizes? A C Burd (1986)
Laboratory Leaflet No 60:	The scientific essentials of fisheries management and regulations D J Garrod (1987)
Laboratory Leaflet No 64:	Stability and the objectives of fisheries management: the scientific background J G Shepherd (1990)
Laboratory Leaflet No 70:	Aide memoire on scientific advice on fisheries management J G Shepherd (1992)

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No. 53	Prospects for fuller utilisation of UK fish meal capacity. 1981.
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No. 55	Rockall and its fishery. 1982.
No. 56	Scad in the North-east Atlantic. 1983.
No. 57	The use of anchored gill and tangle nets in the sea fisheries of England and Wales. 1985.
No. 58	Why increase mesh sizes? 1986.
No. 59	The bass (*Dicentrarchus labrax*) and management of its fishery in England and Wales. 1987.
No. 60	The scientific essentials of fisheries management and regulations. 1987.
No. 61	The North Sea cod and the English fishery. 1988.
No. 62	Crayfish culture. 1990.
No. 63	Cultivation of Pacific oysters. 1990.
No. 64	Stability and the objectives of fisheries management: the scientific background. 1991.
No. 65	Cultivation of Manila clams. 1991.
No. 66	Storage and care of live lobsters. 1991.
No. 67	Cultivation of marine, unicellular algae. 1991.
No. 68	The hatchery culture of bivalve mollusc larvae and juveniles. 1991.
No. 69	Gill netting. 1991.
No. 70	Aide memoire on scientific advice on fisheries management. 1992.